2013

GEOL 440/840: Tectonics—A Peer Review of Teaching Project Inquiry Portfolio

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Peer Review of Teaching Inquiry Portfolio

Course: GEOL 440/840, Global Tectonics

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Introduction

This document is a follow-up document to the Benchmark Portfolio for this course, created in 2012. It details the changes made to the course following the observations from the Benchmark Portfolio and demonstrates that discussion of the metacognitive issues surrounding critical thinking does have some effect on increasing student learning. The document concludes with changes which will be made to the 2014 iteration of the class, to continue this inquiry and improvement process.

PART I: Background to the Issue Being Investigated

Course Description

The course (GEOL 440/840) is about global tectonic events from the Archean to the present day. The Tmaterial is presented from a Laurentian reference frame, since this is where we are all based. However, students are expected to contrast Laurentian tectonic events with global tectonic events e.g. the Appalachian-Caledonide orogney.

The students are upper-level undergraduates and graduate students, all majoring in geology. The students bring a variety of backgrounds to the course – many are focusing on structure and tectonics, but others are focusing on sedimentology or petroleum.

The course is not a mandatory part of the undergraduate curriculum but is suggested for those students who do well and are interested in the mandatory Structural Geology course, GEOL 340. The course is required for graduate students within my research group. Other graduate students are often interested in the course if I am serving on their supervisory committees. There is no known or planned overlap with courses in other departments. The course is complementary to other courses that I teach namely Geophysics, Structural Geology and Advanced Structure.

Course History & Development

GEOL 440/840 has been listed as a course on the Bulletin for a number of years and was taught by my predecessor, although she did not leave material for subsequent use. I have taught the class once before (during the Spring semester of 2012) and was responsible for developing the material that was presented in that first iteration of the course. I drew on material presented in Historical Geology, taught by my colleague Dr. Tracy Frank, and on material developed for my summer class, Geology of North America.

The course was the subject of a Benchmark Portfolio in Spring 2012, for the UNL Peer Review of Teaching Project. This process identified several problems in the course assessment, namely that the grading rubric was not testing content, thus a fresh rubric has been developed, which will be implemented in Spring 2013. In addition, several scaffolding assignments which are currently optional

will be more heavily emphasized (paper outline, rough draft). In the previous iteration of the course, those students who did use scaffolding, such as turning in a rough draft of a paper, demonstrated significantly improved performance on the final paper. This Spring, the paper outline will be heavily emphasized, but not mandatory, to see whether this more structured approach improves the readability and content of the final result. Lastly, course notes and some class activities will be modified and amended to be more interactive, since the desired emphasis on critical thinking was not made during the first iteration.

Course Goals

Learned outcomes and course goals are as follows:

(1) Specific to Global Tectonics

- Describe key parts of Earth's tectonic history from the Archean to the present
- Recognize evidence of Plate Tectonic Processes
- Evaluate evidence for/against Plate Tectonic theory & the origins of modern day plate tectonics
- Reconstruct the tectonic history of any given area from maps, cross-sections and literature
- Analyze the effects of tectonic activity on other global cycles and earth systems

(2) General scientific development

- Construct a coherent research paper detailing the tectonic history of a given area
- Logically construct and defend a point of view from often limited evidence
- Integrate information from various geologic sub-disciplines as relevant

The thought processes behind these goals are as follows. In order to have a complete grasp of plate tectonic processes, students need to understand plate tectonic theory, the ramifications thereof, and evidence for and against certain elements of this theory and certain variations of the theory. They also need to know key events in the tectonic history of the Earth and key events linking other earth systems to plate tectonic theory. They should be able to evaluate evidence for early Plate-Tectonic type processes and defend their argument (which also targets the repeated application of the scientific method, crucial in any STEM field). Specific to geology, the students will learn how to reconstruct things from often very limited evidence and to defend those interpretations. This is a key element of fieldwork – geology is all about conclusions from limited datasets. This skill requires clear thinking and crisp and logical deductions. In addition, they should learn that, as senior or graduate students, they are nearly on the cusp of becoming researchers and that they have the critical thinking skills necessary to make logical and defensible deductions.

Students should know how to recognise evidence of plate tectonic processes and be able to reconstruct the tectonic history of any given area, from maps and cross-sections and literature. They should be

able to write the tectonic history of an area of interest to themselves, e.g. their field area, their research area, their home state. In addition, student perspectives need to get away from being mid-western centered, so that although the course will start with a Laurentian focus, they should be familiar with key examples from the rest of the world. During teaching time, we will compare events in NE to events in other parts of Laurentia/Gondwana as appropriate. In this fashion, the students will a) be developing the tectonic history of their own region and b) listening to other perspectives, gaining a global view and c) comparing and contrasting the varied expression of similar events across different parts of the world

Students need to achieve these goals because, whatever the field of study, being able to reconstruct the geologic and tectonic history of an area is an important stage in the background understanding of the area and slotting one's research into the correct setting. Having the correct setting and an understanding of that setting allows for careful and accurate analysis of the rocks/organisms/whatever in the study area without invoking forces or situations that are untenable or impossible.

Issue Under Investigation

The issue to be studied is a "what works" question (per Hutchings) concerning the development of critical thinking, and conveying the results of that critical thinking in the course. Critical thinking is assessed by the two papers turned in during the class – testing whether students can "interpret, understand, process and apply the course concepts to new situations" (Savory et al). This is a useful issue to be investigated, since the reflective process behind the creation of the Benchmark Portfolio for this course in Spring 2012 highlighted issues in the way that these main assessments are implemented in the class, and how these assessments are graded. The data collected as part of the Benchmark Portfolio indicates the importance of scaffolding assignments (paper outline and rough draft) in improving the quality and readability of the final papers. In addition, the grading rubric was found to be inadequate for assessing critical thinking, and a fresh rubric has been drafted. Focusing on the critical thinking aspect of this class, and investigating the results of implementing new requirements on assessments will help resolve the problems identified in the previous reflective process. Investigating this issue will contribute to the students' ability to frame and clearly articulate the arguments, and improve their critical thinking skills. I also anticipate this process making the class more interactive, as class activities are adjusted to encourage critical thinking. It is possible that this investigative process will become a useful example of scholarly teaching but I do not anticipate this becoming a key study in scholarship of teaching and learning literature.

The issue of implementing and assessing critical thinking assignments more carefully became obvious in the final stages of the Benchmark Portfolio, where I realised that the grading rubric that I had written was grading the form and style of the final papers but not the content, or the evidence presented for critical thinking processes. This issue probably arises from my inexperience in designing and implementing grading rubrics and teaching styles such as scaffolding assignments. A wider context for this problem is that there is no systematic class or teaching of writing for the students in Earth and

Atmospheric Sciences and thus it is possible that this class is the first time that the students have been required to write a significant geologic paper. Since Spring 2013 is only the second iteration of this course, nothing has yet been implemented to address this issue.

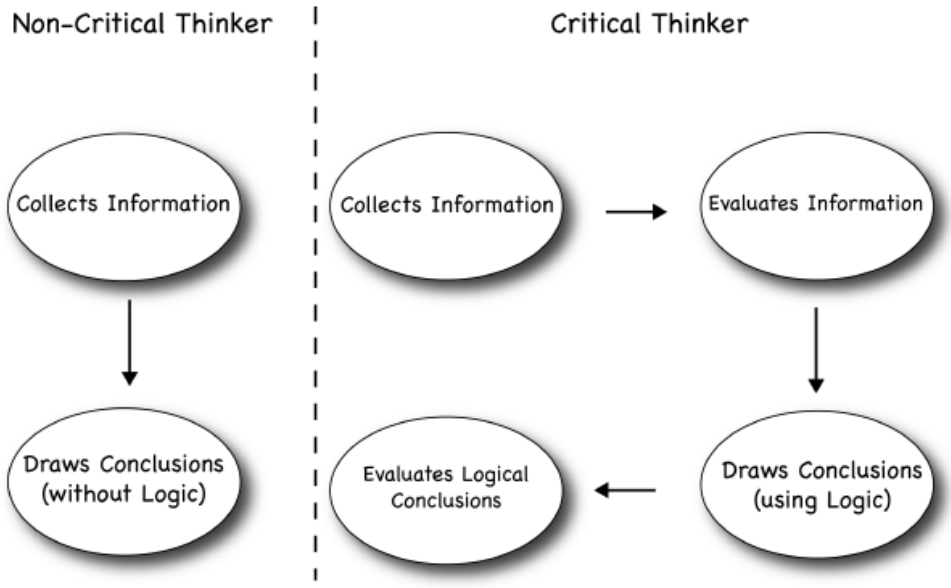
There are two main assignments where the students are required to present evidence of critical thinking. These are a mid-term paper on Plate Tectonics, and a final paper on the tectonic development of two different, but complementary regions. These will now come with a mandatory scaffolding assignment of creating a paper outline and rough draft to turn in ahead of the final draft. Class activities throughout the course were intended to encourage critical thinking but on reflection, could be improved. Lecture notes also need to have

Ideally, the grades for the final papers will show improvement over the interim grades for the rough draft, and an improvement over the grades for the draft/final version of the mid-term paper. In addition, it is hoped that Spring 2013 averages and statistics will show an improvement over the statistics for Spring 2012. This improvement will test whether the students' ability to convey the results of their critical thinking processes has improved. These data are expected to be a proxy for whether the students' ability to actually think critically has improved. In addition, student grades for presentations during Spring 2012 will be compared to grades for presentations in Spring 2013, to form another method of measuring the same things, namely critical thinking and the ability to convey the results of this critical thinking.

PART II: Methodology

Inquiry Scope

The issue being studied in this project concerns the development of critical thinking and the ability to convey the results of this critical thinking in students taking GEOL 440/840 in Spring 2013. Critical thinking is defined here as "thinking carefully with clarity, depth, precision, accuracy and logic" and is summarized in the following diagram:



Having observed a number of upper level and graduate students in this and other classes, as well as those under my guidance as research students, it appears that data collection and preliminary analysis, and the presentation of facts, are skills that the students already possess. However, the critical thinking aspects, the ability to synthesize this information and to draw information from other areas of geology and to draw conclusions and implications, are not skills generally possessed at a high level, by this group of students. Some students are able to carry out these tasks at a high level, but others are apparently unable to make the leaps of critical or logical thought necessary.

An additional aspect of this issue is whether the students are unable to carry out these critical thinking tasks because of lack of experience and practice, or from lack of guidance in HOW to think critically. This corollary question could be addressed by a survey of the previous classes that students have taken and the critical thinking aspects of teaching in these classes, and a survey of student perception of their own experience/ability to think critically. This will be done via a pre-semester survey and a pre-semester test, collecting information about their attitudes and perceived abilities and their actual abilities respectively. After this, I will find out what the syllabus in each of the precursor courses looks like (assuming other faculty agree) and thus be able to form a hypothesis on why the issue is occurring – lack of practice, lack of guidance, some other reason. This will govern the future offerings of the course.

Specific Research Question

There are many aspects that could be modified and studied in this course, based on previous offering and the results identified in the Benchmark Portfolio already prepared for this class. The central research question is:

"What is the effect of a change in teaching style on student critical thinking?"

Methods of Inquiry

This will be addressed by an overhaul of the course to implement critical thinking aspects and exercises throughout the class, rather than the emphasis on presentation of facts and information as occurred in the previous offering. This means that the front end class notes are different from the previous class and the effect of this change in teaching style is what is essentially being assessed.

The possible variables for this study are as follows:

- Dependent
    - Pre-semester survey and test
    - Post-semester test and reflective exercise
    - Outline/rough draft/final version of the midterm paper
    - Presentations 1 & 2
    - Outline/rough draft/final version of the final paper

- Independent
    - Attendance & Lateness
    - Grades/grade breakdowns for assignments/segments of assignments
    - Statistical distribution of grades for assignments
    - Student progress/grade trajectory as the semester progresses
    - Grades on pre/post semester tests
    - Student attitudes and perceived ability in pre-semester test
    - Modified class notes from previous offering

Data Collection

Data will be collected as part of the normal class assessment procedure. Data will be collected at intervals throughout the semester - but dominantly in the mid-term and final "exam" periods. All work from all students who give permission for work to be included will be collected, since the class is usually small (between 6-12 persons). The sample size is not large, hence this study will explore this issue longitudinally over a series of years, to maximize the sample size and lend rigor to the results.
Classroom evidence collected will be as follows:

- Pre-semester test and grades
- Post-semester test and grades
- Outline or rough draft from the midterm paper and grades (scaffolding assignment)
- Final version of the midterm paper and grades
- Grades from presentations 1 & 2 and comments
- Outline or rough draft from the final paper and grades (scaffolding assignment)
- Final version of the final paper and grades

These will all be routinely collected as part of the assessment for this class, thus there is no need for IRB permissions.

Other data that may be collected, depending on time available includes:

- Student attitudes and perceived ability from pre-semester survey
- Syllabus notes and scheduled exercises from precursor courses
- Consultation with GeoEducation specialists in department (Dr. Leilani Arthurs or Dr. Mindi Searls)
- Pedagogical literature survey

Assumptions and Anticipated Difficulties

The key assumptions being made in this project are:

- That the student population essentially remains the same
- That the main change to the course IS the course notes and the manner of teaching so I really am assessing the impact of my teaching style on their critical thinking
- That the instruments used for measurement are valid and provide meaningful results

The main difficulty anticipated in this study is the small sample size, thereby making it hard to draw valid conclusions that are statistically significant. An additional potential difficulty is my concern that the grading rubrics and exercises have not been through sufficient iterations to be sure that they are testing what I think they are testing or grading. Both difficulties can be overcome by making this a multi-year longitudinal study and incorporating data from the 2014 and 2015 offerings of this class as well.

PART III: Analysis and Assessment of the findings

Changes Made to the Course Between 2012 and 2013

Changes made in 2013 relative to 2012 are the changes to the grading rubric and an increased emphasis on critical thinking discussion and activities at the front end of the course – see appendices A and B for the altered course schedule and some examples of the more critical-thinking-oriented lectures at the front end. Some of these changes have also been documented as proposed changes in the accompanying Benchmark Portfolio created for this course during 2012.

The 2013 offering of the course is compared to the control set, i.e. the 2012 offering of the course, before changes were made to the teaching style and to the grading rubrics. This is a valid control set, since the class demographics are similar (approx. 30% graduate students, 70% undergraduate students) in each year, although the class size increased from 6 to 10 from 2012 to 2013. In 2013, there were actually 12 students initially registered, one of whom converted to auditing the class because of a substantial credit load and one of whom was forced to leave UNL mid-semester because of his personal situation. Thus the actual attrition rate (students who dropped out because of the class itself) was 0 in each year.

In order to carry out this comparison to a control group, after a change in teaching style, the papers from 2012 were re-graded using the new 2013 rubric. A clear limitation of this is that I, as grader, was not blind to my hypothesis: “changing teaching style will increase student critical thinking” and that the grading may not have been totally independent.

Based on the changes made to the class I would expect the grades for papers and presentations to increase, and for specific sections of the grade for each paper to increase. I would also expect the grades for the post-test to be somewhat higher than the grade for the pre-test. Each segment will be analyzed separately and then some general comments on the class will be made.

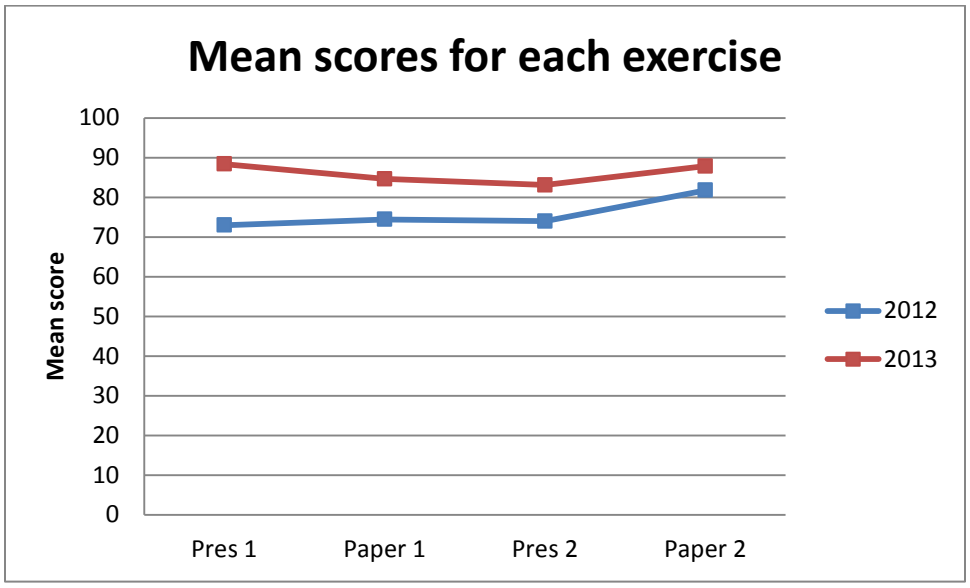
Testing for Improved Critical Thinking and Argument Creation

This is carried out by assessing two presentations and two papers during the semester. This requires the students to construct and defend an argument and the implications of that argument, based on literature and on map and cross-section interpretation.

Overall Results

A number of overall trends can be noted within the data, as displayed in the following table and chart. The mean percentage score for each exercise is tabulated for each year and then plotted.

Year	Presentation 1	Paper 1	Presentation 2	Paper 2
2012 (n = 6)	73.00	74.44	74.00	81.79
2013 (n = 10)	88.40	84.63	83.1	87.85



The observable trends are as follows:

- During 2012, there is a gradual increase in scores throughout the semester, as expected.
- During 2012, Paper 2 shows a large increase in score over Paper 1; again as expected
- 2013 scores are consistently higher than 2012 scores; although only the score increase for Presentation 1 is statistically significant
- During 2013, the scores for each exercise do not show statistically significant variation - paper 2 shows a slight increase in mean score relative to paper 1; presentation 2 shows a slight decrease in mean score relative to presentation 1.

An alternative way of viewing the changes between different exercises and different years is a matrix comparing the exercises as a percentage increase or decrease, as displayed below. This highlights the increases in scores between 2012 and 2013; and also indicates that the increases in scores are less marked as the semester continues – e.g. only a 7% increase in paper 2 (the final exercise) from 2012-2013 compared to the 21% increase observed for the first exercise, presentation 1.

	Subsequent								
Original		Pres 1 2012	Pres 2 2012	Paper 1 2012	Paper 2 2012	Pres 1 2013	Pres 2 2013	Paper 1 2013	Paper 2 2013
	Pres 1 2012		+ 1% wrt Pr1			+21% in 2013			
	Pres 2 2013						+12% in 2013		
	Paper 1 2012				+10% wrt P1			+14 % in 2013	
	Paper 2 2012								+7% in 2013
	Pres 1 2013						-6% wrt Pr1		
	Pres 2 2013								
	Paper 1 2013								+4% wrt P1
	Paper 2 2013								

The implication is that there is some increase in score that can be attributed to the front end changes, but that for some reason, student effort/work something is tailing off towards the end of the semester. Possible reasons for this are:

- Students are spending less time on task in the time crunch at the end of the semester
- Discussions of metacognitive processes (i.e. critical thinking) are emphasized towards the front end of the semester and less towards the end of the class

Presentations

The students give two presentations during the semester, one in the mid-term period and one at the end of the semester, graded out of 50. The rubric for the presentations has not changed between 2012 and 2013, thus no re-grading is necessary and the 2012 group can serve as a true control group. The key differences between the grades are shown in the following table:

Assignment	Mean score	Upper error bar	Lower error bar
Presentation 1 2012	36.5	39.1	33.8
Presentation 2 2012	37.0	39.6	34.4
Presentation 1 2013	44.2	47.5	40.9
Presentation 2 2013	41.5	44.9	38.2

The difference in mean score in presentation 1 between the two years is statistically significant and shows the desired improvement. However the difference in means for presentation 2 between the two years is not significant due to the overlap in error bars. These error bars are based on the approximation upper/lower bound = mean ± √(n+1) which is valid for small n and approximates the standard deviation of the dataset.

Paper 1

The grading rubric for paper 1 was changed between the 2012 iteration of the course and the 2013 iteration of the course. As described above, the 2012 papers were re-graded based on the 2013 rubric to form an approximate control group. Overall statistical data for 2012/2013 is presented in the following table, showing a significant increase in mean score in the 2013 group relative to the 2012 group. Grading categories which are concerned with writing mechanics are italicized and those which are expected to show marked increases based on the change in teaching are left in plain text.

Category	**2012**				**2013**			
	Mean	**Max**	**Min**	**Range**	**Mean**	**Max**	**Min**	**Range**
Thesis	*8.67*	*10*	*7*	*3*	*8.44*	*10*	*5*	*5*
Introduction	*7.67*	*10*	*5*	*5*	*7.89*	*9*	*5*	*4*
General Content	7.00	10	5	5	8.89	10	8	2
Description of PT setting	8.17	10	7	3	8.78	10	7	3
Evidence of PT processes	7.33	9	8	4	8.78	10	7	3
Organization	*7.17*	*10*	*5*	*5*	*7.89*	*9*	*5*	*4*
Tone	*7.33*	*10*	*4*	*6*	*8.89*	*10*	*6*	*4*
SPAG	*6.50*	*8*	*4*	*4*	*7.78*	*10*	*5*	*5*
Conclusions	*7.00*	*9*	*5*	*4*	*8.00*	*10*	*4*	*6*
Reference quality	*9.83*	*10*	*9*	*1*	*9.44*	*10*	*7*	*3*
Citations	*5.00*	*8*	*2*	*6*	*7.00*	*10*	*3*	*7*
Research Effort	*7.67*	*10*	*5*	*5*	*9.78*	*10*	*8*	*2*
Final %	**74.4**	**94.2**	**56.7**	**37.5**	**84.6**	**94.1**	**60.8**	**33.3**

It can be seen that the mean final score is higher in 2013 than in 2012, and this is statistically significant. It can also be noted that within the three crucial categories targeting content, the means are higher in 2013 than 2012, although this difference is not statistically significant, using the approximation for small n as follows: upper/lower bound = mean ± √(n+1).

Paper 2

The grading rubric for paper 2 was also changed between the 2012 iteration of the course and the 2013 iteration of the course. As described above, the 2012 papers were re-graded based on the 2013 rubric to form an approximate control group. Overall statistical data for 2012/2013 is presented in the following table, showing a slight increase in mean score in the 2013 group relative to the 2012 group. This difference is just statistically significant. Grading categories which are concerned with writing mechanics are italicized and those which are expected to show marked increases based on the change in teaching are left in plain text.

Category	**2012**				**2013**			
	Mean	**Max**	**Min**	**Range**	**Mean**	**Max**	**Min**	**Range**
Thesis	*9*	*10*	*8*	*2*	*8.40*	*9*	*8*	*1*
Introduction	*8.67*	*10*	*8*	*2*	*9.10*	*10*	*8*	*2*
General Content	8.67	10	7	3	9.50	10	7	3
Description of tectonic setting	8.33	9	7	2	9.40	10	7	3
Maps & cross-sections	5.5	9	4	5	7.50	9	5	4
Analysis of earth systems	7.17	8	6	2	7.60	10	7	3
Organization	*9*	*10*	*7*	*3*	*8.60*	*10*	*5*	*5*
Tone	*8.5*	*10*	*6*	*4*	*9.70*	*10*	*8*	*2*
SPAG	*7.17*	*9*	*5*	*4*	*8.00*	*10*	*5*	*5*
Conclusions	*8.17*	*10*	*7*	*3*	*8.80*	*10*	*8*	*2*
Reference quality	*9.67*	*10*	*9*	*1*	*9.90*	*10*	*9*	*1*
Citations	*7.33*	*10*	*4*	*6*	*7.80*	*10*	*5*	*5*
Research Effort	*9.17*	*10*	*8*	*2*	*9.90*	*10*	*9*	*1*
Final %	**81.8**	**91.5**	**66.9**	**24.6**	**87.8**	**93.8**	**76.9**	**16.9**

It can be seen that the mean final score is higher in 2013 than in 2012, and this is also a statistically significant difference. It can also be noted that within the four crucial categories targeting content, the means are higher in 2013 than 2012, although this difference is not statistically significant, using the approximation for small n as follows: upper/lower bound = mean ± √(n+1). There is a pleasingly large jump in the "maps and cross-sections" section – from a mean of 5.5 to 7.5, and although the error bars do overlap, the individual scores indicate that more students are grasping the concept of including suitable figures in a paper.

Summary

All documented data above indicates that the change in teaching style, to include a discussion of metacognitive aspects of the class including the emphasis on critical thinking has had some positive effect on the scores from one year to the next. The 2012 section is the control group and changes were made before the 2013 class iteration which has had a beneficial effect on the student scores and therefore learning. Possible solutions to the drop-off in scores at the end of the semester in 2013 will eb discussed later.

Testing for Mastery of Map Evaluation

A pre-semester exercise is set in this class, looking at three different maps of N America and requiring the students to divide the continent up into different provinces. This map interpretation style exercise is important in assessing whether the students can defend their decisions and make an argument; and also a test of the knowledge of the geology of the country that they gain throughout the course. The questions posed are:

- How have you divided the continent up?
- How many different provinces do you have? Describe them.
- What plate tectonic settings do you have for the various divisions?

Each answer is given a score based on a simple rubric, as below:

Question	1 point	3 points	5 points
How have you divided the continent up?	Reliance on 1 map	Some attempt to synthesize 2 maps; perhaps starting from previous knowledge	Attempt to synthesize and describe using all 3 maps
How many different provinces do you have? Describe them	1-3 divisions	4-6 divisions	More than 6 divisions
What plate tectonic settings do you have for the various divisons?	I don't know	List of terms, partially correct; names of provinces but no explicit setting	Correct settings given for all defined provinces, NOT just names or provinces

At the end of the semester, the students are given the same exercise to do and the results are compared, as shown in the following table. Blank spaces indicate that the student didn't complete the post-semester exercise.

Student	Pre – Q1	Pre – Q2	Pre – Q3	**TOTAL**	Post – Q1	Post - Q2	Post – Q3	**TOTAL**	**Change?**
MA	4	1	3	**8**					
JoB	3	4	4	**12**	3	5	4	**12**	**0**
JeB	1	3	1	**5**					
EC	3	1	1	**5**	3	3	3	**9**	**+4**
JT	3	4	1	**8**					
DJ	3	3	3	**9**	3	3	3	**9**	**0**
AJ	1	3	5	**9**	1	3	5	**9**	**0**
AP	4	3	3	**10**	4	3	4	**11**	**+1**
GP	1	3	1	**5**	1	3	3	**7**	**+2**
ER	5	3	1	**9**	5	3	3	**11**	**+2**
			Mean	**8**			Mean	**9.7**	

Although there is a slight increase in mean score, using an approximation to the standard error based on small n, that is error bar = mean ± √(n+1) reveals that the error bars overlap thus the difference in the mean scores is not statistically significant. In addition, individual students typically show no increase in scores or a small increase in their score (notable exception being student EC whose score has nearly doubled).

Summary

The result described above is not the ideally expected result, based on the change in teaching as discussed above. Possible reasons for this are as listed:

- Students not taking the exercise seriously at the end of the course
- The students are not meeting the objectives set for them
- The exercise itself is set up poorly so that the students are not answering the question I thought that I was posing.

At this stage, with only one dataset, it is difficult to estimate exactly which of these three is the most likely solution. The exercise did not form part of the credit given for the course but was an extra exercise, thus the students may not have been taking it seriously. Given improvements in student learning documented through the papers and presentations, the students are meeting the objectives set for them, thus I suspect that factor 2 is not the main contributing factor in this instance. In comparing the answers that the students gave for the questions to the "expert" answers, I suspect that factor 3 is the most important factor – the exercise questions are not phrased correctly and the question the students are reading is not the question that I thought that I was posing.

Proposed Changes for the 2014 Course Iteration

Based on the data discussed above, two changes will be made to the class in the 2014 course offering, to continue targeting the effect of teaching style on student critical thinking. One change is based on the results from the exercises targeting critical thinking, and one on the results from the pre/post semester exercise.

Related to the papers and presentations, the key change that will be made to the course is an increased emphasis on discussing the metacognitive aspects – i.e. what I want the students to be learning – throughout the entirety of the course, rather than at the front end only. This was highlighted as a possible factor in the slightly lower grade improvement in paper/presentation 2 between 2012 and 2013.

Regarding the pre/post semester exercise, the conclusion that can most reasonably be drawn at this point in the inquiry process is that the instrument being used to measure critical thinking and learning is not the best instrument for the task at hand. Thus, in the 2014 iteration of the class, I will both include this exercise in the credit for the class, to avoid students not taking the exercise seriously, and I will rephrase the questions to be more specific about what I am actually asking for, as follows:

- What data did you use to divide up the continent?
- How many different regions do you have? Describe each one in terms of the data you used to define it.
- For each region, suggest what plate setting or plate boundary type must have formed it.

Final comments

Similar data will be collected in the 2014 offering of this class, transforming this study into a longitudinal study with three years of data. This gives me time to test the hypothesis that continued emphasis on critical thinking throughout the course, rather than just at the front end, improves student learning and understanding, as measured in their scores.

Appendices

Appendix A – Course Schedules, 2012 and 2013

Key changes are highlighted at the front end of the course.

Expected Schedule and important deadlines 2012

Week	Date	Topic	*Notes*
1	9 Jan 2012	Basics of Plate Tectonics **Study area 1 selected by F**	
2	16 Jan 2012	Archean Tectonics	*No class M*
3	23 Jan 2012	Archean Tectonics **Study area 2 selected by M**	*No class F*
4	30 Jan 2012	Proterozoic Tectonics *Paper 1 outline due F*	
5	6 Feb 2012	Proterozoic Tectonics	
6	13 Feb 2012	Paleozoic Tectonics	
7	20 Feb 2012	Paleozoic Tectonics *Paper 1 draft 1 due M*	
8	27 Feb 2012	Plate Tectonics Now & Then **Class Presentations W/F**	
9	5 Mar 2012	**Mid-term paper due Fri in class** Review session	*No class M/W*
10	12 Mar 2012	Mesozoic Tectonics	
	19 Mar 2012	SPRING BREAK	
11	26 Mar 2012	Mesozoic Tectonics *Paper 2 outline due F*	
12	2 Apr 2012	Cenozoic Tectonics	
13	9 Apr 2012	Cenozoic Tectonics *Paper 2 draft due M*	
14	16 Apr 2012	Earth Systems Science **Class Presentations W/F**	
15	23 Apr 2012	Review Session	*No class M/W*
16	30 Apr 2012 Finals week	**Final Paper Due Mon, 5pm**	*No final exam*

Expected Schedule and important deadlines – 2013

Week	Date	Topic	*Notes*
1	7 Jan 2013	Introductory Exercise Basics of Plate Tectonics **Study area 1 selected by F**	**** notes changed from 2012*
2	14 Jan 2013	Plate Tectonics Now & Then	**** notes changed from 2012*
3	21 Jan 2013	Archean Tectonics **Study area 2 selected by W**	*No Class M*
4	28 Jan 2013	Archean Tectonics *Paper 1 outline due F*	
5	4 Feb 2013	Proterozoic Tectonics	
6	11 Feb 2013	Proterozoic Tectonics	
7	18 Feb 2013	Paleozoic Tectonics *Paper 1 draft 1 due M*	
8	25 Feb 2013	Paleozoic Tectonics **Class Presentations F if needed**	
9	4 Mar 2013	**Class Presentations M/W/F** **Mid-term paper due Fri in class** Possible Review session!	**** review added from 2012*
10	11 Mar 2013	Mesozoic Tectonics	
	18 Mar 2013	SPRING BREAK	
11	25 Mar 2013	Mesozoic Tectonics *Paper 2 outline due W*	*No Class F*
12	1 Apr 2013	Cenozoic Tectonics	
13	8 Apr 2013	Cenozoic Tectonics *Paper 2 draft due M*	
14	15 Apr 2013	Earth Systems Science **Class Presentations F if needed**	**** planned in 2013 but not carried out, as time was short*
15	22 Apr 2013	**Class Presentations M/W** Review Session & Exercises	
16	29 Apr 2013 Finals week	**Final Paper Due Mon, 5pm**	*No Final Exam*

Appendix B – Examples of Front-End Lectures, 2012 and 2013

Global Tectonics

Dr. Cara Burberry

Logistics/Syllabus etc

- Class will meet from 1.30-2.20, MWF
- Feel free to bring coffee with you
- Classes will be a mixture of lecture and activity – please come prepared to sketch/think/discuss ideas within the group. I have no need to hear my own voice all the time.
- If you have questions, please feel free to interrupt & ask.
- Enjoy!
- Syllabus – coming soon. Honest.

Geological Provinces of N America

- Map interpretation exercise... Definitions first!
- Gravity anomaly
  - difference between observed & theoretical gravity values at a given point. Various corrections can be used. Anomalies are related to the differences in subsurface mass distribution & potentially represent variations in geological structure

AGI definition

Geological Provinces of N America

- Magnetic anomaly
  - difference between observed & theoretical magnetic susceptibility values at a given point. Various corrections can be used. Anomalies are related to the differences in subsurface magnetic susceptibility distribution & potentially represent variations in geological structure

AGI definition

Geological Provinces of N America

ACTIVITY 1

- Looking at the gravity anomaly and magnetic anomaly maps of N America, sketch onto your own maps the possible divisions of N America into geologic blocks.
- Be prepared to defend your divisions!

Geological Provinces of N America

- How have you divided the continent up?
- How many different provinces do you have?
- Was it confusing trying to combine the two maps?
- What present-day features of the continent do your divisions coincide with?


QUESTIONS?

Global Tectonics

Dr. Cara Burberry

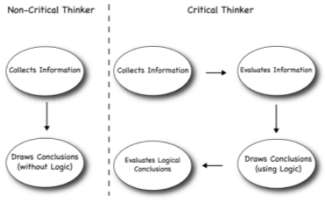
Logistics/Syllabus etc

- Class will meet from 10.30-11.20, MWF
- Feel free to bring coffee with you
- Classes will be a mixture of lecture and activity – please come prepared to sketch/think/discuss ideas within the group. I have no need to hear my own voice all the time.
- If you have questions, please feel free to interrupt & ask.
- Enjoy!
- Paperwork… – voila!

OVERALL GOAL

- Critical thinking!

Critical thinking is defined here as "thinking carefully with clarity, depth, precision, accuracy and logic" and is summarized in the following diagram:



OVERALL GOAL

- Critical thinking!
- Questions:

Context and motivation:
What is the main argument of the paper and why is it significant? Why did the authors write the paper or do the work in the first place? Why would anyone want to read it?

Data and analysis:
What's the evidence?
How are the data presented and why?
Are the tools or instruments appropriate?
Is the data analysis adequate?
What are the assumptions and what are the fundamentals that allow you to make these assumptions?

Geological Assessment:
Is this consistent with what we know already? Is there something inconsistent with this work?
So is this "outlier" important? A new discovery or that someone has screwed up or it's a glitch?
Are there alternative hypotheses that could come from the data?
Is this possible, probable, or excluded (expected, permissive, doubtful, or excluded).
Need to go beyond emulating to the intentional and purposeful
What constitutes evidence?

http://serc.carleton.edu/NAGTWorkshops/metacognition/group_tactics/28890.html

Geological Provinces of N America

- Map interpretation exercise... Definitions first!
- Gravity anomaly
  - difference between observed & theoretical gravity values at a given point. Various corrections can be used. Anomalies are related to the differences in subsurface mass distribution & potentially represent variations in geological structure

AGI definition

Geological Provinces of N America

- Magnetic anomaly
  - difference between observed & theoretical magnetic susceptibility values at a given point. Various corrections can be used. Anomalies are related to the differences in subsurface magnetic susceptibility distribution & potentially represent variations in geological structure

AGI definition

Geological Provinces of N America

ACTIVITY 1

- Looking at the gravity anomaly, magnetic anomaly and modern topographic maps of N America, sketch onto your own maps the possible divisions of N America into geologic blocks.
- Be prepared to defend your divisions! Try to put them into a modern PT context

Geological Provinces of N America

- How have you divided the continent up?
- How many different provinces do you have?
- What plate tectonic settings do you have for the various divisions?
- *It doesn't matter if the answer to the latter question is "I don't know". I will pose the same question at the end of the course and see what you have learned*.

TO DO

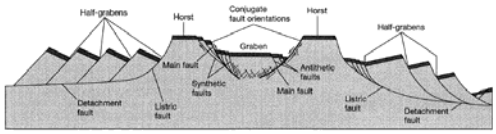
- Take the critical thinking practice test to see how you are doing on CT. Let me know your score via email.
- http://ww2.nscc.edu/depart/testing/ctreview.htm
- Read – material on CT on BB

QUESTIONS?

What do we expect at a MOR?

- Think about the processes occurring, the rock types you might expect to generate…

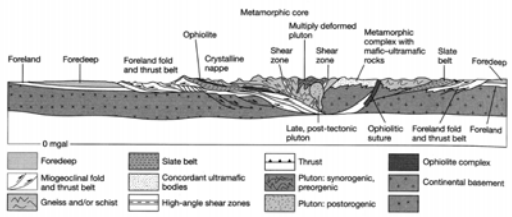
In XS…



What do we expect at a subduction zone?

- Think about the processes occurring, the rock types you might expect to generate…

In XS…



What do we expect at a S/S boundary?

- Think about the processes occurring, the rock types you might expect to generate…

What do we expect where there have been OIBs?

- Think about the processes occurring, the rock types you might expect to generate…

For you to do…

1. Read… Textbook Ch 1 & 2
2. Think about your study area!